In re Patent Application of: Hitoshi Asahi et al.

Serial No. 10/518,663 Examiner: Deborah Yee
Filed: December 17, 2004 Group Art Unit: 1742
For: OIL COUNTRY TUBULAR GOODS EXCELLENT IN COLLAPSE CHARACTERISTICS AFTER EXPANSION AND METHOD OF PRODUCTION THEREOF

TRANSLATOR'S DECLARATION

Honorable Commissioner of Patents & Trademarks
Washington, D.C. 20231

Sir:

I, Masaki Honda , residing at c/o SEIWA PATENT & LAW, Toranomon 37 Mori Bldg., 3-5-1, Toranomon Minato-ku, Tokyo 105-8423, Japan declare the following:

(1) That I know well both the Japanese and English languages;

(2) That I translated Japanese Patent Application No. 2002-178770, filed June 19, 2002 , from the Japanese language to the English language;

(3) That the attached English translation is a true and correct translation of the aforesaid Japanese Patent Application No. 2002-178770 to the best of my knowledge and belief; and

(4) That all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and that such false statements may jeopardize the validity of the application or any patent issuing thereon.

September 14, 2007

Date

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[NAME OF DOCUMENT] APPLICATION FOR PATENT

[REFERENCE NUMBER] 1024095

[DATE FILED] June 19, 2002

[DESTINATION] To Commissioner, Patent Office: Mr. Kozo Oikawa

[INTERNATIONAL PATENT CLASSIFICATION] C22C 38/00
B01B 1/00

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[INDICATION OF FEES TO BE PAID]

[Registration Number for Prepayment]	036135
[Amount Fee]	21,000 yen

[LIST OF ARTICLES TO BE SUBMITTED]

[Name of Article]	Specification	1
[Name of Article]	Abstract	1
[General Authorization Number]		0018106

[NEED FOR PROOF] yes

[Name of the document] SPECIFICATION

[Title of invention] A METHOD FOR PRODUCING AN OIL COUNTRY TUBULAR GOODS EXCELLENT IN COLLAPSE CHARACTERISTICS AFTER EXPANSION

[Claims]

[Claim 1] A method of production of oil country tubular goods excellent in collapse characteristics after expansion characterized by hot rolling a slab containing, by wt%:

C: 0.03 to 0.3%,
Si: 0.8% or less,
Mn: 0.3 to 2.5%,
P: 0.03% or less,
S: 0.01% or less,
Nb: 0.01 to 0.3%,
Ti: 0.005 to 0.03%,
Al: 0.1% or less, and
N: 0.001 to 0.01% and

comprising a balance of Fe and unavoidable impurities, coiling the strip at not more than 300°C, shaping the hot rolled steel strip into a tube as it is, then welding the seam.

[Claim 2] A method of production of oil country tubular goods excellent in collapse characteristics after expansion characterized by the slab further containing one or more of; by wt%:

Ni: 1% or less,
Mo: 0.6% or less,
Cr: 1% or less,
Cu: 1% or less,
V: 0.3% or less,
B: 0.0003 to 0.003%,
Ca: 0.01% or less, and
REM: 0.02% or less.

[Claim 3] A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to claim 1 or 2, characterized in that a ratio of

collapse pressure after expansion and collapse pressure before expansion is in the range of a/b: 0.85 to less than 1.0, where

a: collapse strength (MPa) after expansion 10 to 20%, and b: collapse strength (MPa) of unexpanded steel pipe of same dimension as steel pipe measured for a.

[Claim 4] A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to any one of claims 1 to 3, characterized in that a ratio of c/d of collapse pressure after expansion and collapse pressure before expansion is in the range of 1 to 1.2, where

c: collapse strength (MPa) after expansion 10 to 20% and aging at 80 to 200°C, and d: collapse strength (MPa) of unexpanded steel pipe of same dimension as steel pipe measured for c.

[Claim 5] A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to any one of claims 1 to 4, characterized in that a welded part is normalized or quenched and tempered.

[Claim 6] A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to any one of claims 1 to 5, characterized in that the seam portions are butt welded.

[Claim 7] A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to any one of claims 1 to 6, characterized in that expanding the pipe by extracting a plug of a diameter larger than the inside diameter of the steel pipe.

[Claim 8] A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to any one of claims 1 to 7, characterized by being used expanded on an oil well drilled into the ground.

[Claim 9] A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to any one of claims 1 to 8, characterized by circulating fluid of 80 to 200°C through the oil well after

expansion.

[Detailed description of the invention]

[0001]

[Technical field of the invention]

The present invention relates to oil country tubular goods suitable as steel pipe used in oil wells for expandable tubular technology creating oil wells or gas wells by expanding oil country tubular goods, featuring little drop in collapse characteristics after expansion, and improved in collapse characteristics by low temperature ageing at about 100°C after expansion.

[0002]

[Prior art]

In the past, oil country tubular goods had been inserted into the wells and used as is, but in recent years technology has been developed for use after expansion 10 to 20% in the wells. This has greatly contributed to the reduction of oil well and gas well development costs. However, if tensile plastic strain is introduced in the circumferential direction due to the expansion, the yield strength with respect to the compressive stress in the circumferential direction due to outside pressure (hereinafter referred to as the "compression yield strength") will drop and the pressure at which the steel pipe collapses due to outside pressure (hereinafter referred to as the "collapse pressure") will drop. This, as is well known as the Bauschinger effect, is the phenomenon where, after plastic deformation, if applying stress in the opposite direction to the direction in which plastic strain was applied, yield occurs by a stress lower than before plastic deformation.

[0003]

The Bauschinger effect occurs due to plastic stress, so a method for restoring the reduced compression yield strength by heat treatment has been disclosed in Japanese Unexamined Patent Publication (Kokai) No. 9-3545 and Japanese Unexamined Patent Publication (Kokai) No. 9-49025 and reported in numerous

research papers. However, if expanding pipe in a well, later high temperature heat treatment is not possible in the well, so steel pipe with little drop in collapse strength after expansion has been sought.

[0004]

[Problem to be solved by the invention]

The present invention provides oil country tubular goods excellent in collapse characteristics with a small rate of drop of collapse pressure due to the Bauschinger effect after expansion in an oil well pipe and further oil country tubular goods excellent in collapse characteristics improved in collapse pressure due to low temperature ageing at near about 100°C able to be performed in an oil well and methods for the production of the same.

[0005]

[Means for solving the problem]

The inventors engaged in detailed studies on steel pipe exhibiting the Bauschinger effect and its recovery behavior and methods of production of the same, in particular ageing and other heat treatment and hot rolling conditions having an effect on the properties of steel pipe. As a result, they discovered that steel having a structure including a low temperature transformation phase obtained by hot rolling, cooling, then coiling at a low temperature of not more than 300°C has a smaller rate of drop of the compression yield strength due to the Bauschinger effect compared with steel coiled at 500 to 700°C, quenched, and tempered and further is restored in the compression yield strength by ageing near about 100°C.

[0006]

The present invention was made after repeated experiments based on these discoveries and has as its gist the following:

(1) A method of production of oil country tubular goods excellent in collapse characteristics after expansion characterized by hot rolling a slab containing, by wt%:

C: 0.03 to 0.3%,
Si: 0.8% or less,
Mn: 0.3 to 2.5%,
P: 0.03% or less,
S: 0.01% or less,
Nb: 0.01 to 0.3%,
Ti: 0.005 to 0.03%,
Al: 0.1% or less, and
N: 0.001 to 0.01% and

comprising a balance of Fe and unavoidable impurities, coiling the strip at not more than 300°C, shaping the hot rolled steel strip into a tube as it is, then welding the seam.

(2) A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to (1), characterized by the slab further containing one or more of; by wt%:

Ni: 1% or less,
Mo: 0.6% or less,
Cr: 1% or less,
Cu: 1% or less,
V: 0.3% or less,
B: 0.0003 to 0.003%,
Ca: 0.01% or less, and
REM: 0.02% or less.

(3) A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to (1) or (2), characterized in that a ratio of collapse pressure after expansion and collapse pressure before expansion is in the range of a/b: 0.85 to less than 1.0, where

a: collapse strength (MPa) after expansion 10 to 20%, and b: collapse strength (MPa) of unexpanded steel pipe of same dimension as steel pipe measured for a.

(4) A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to any one of (1) to (3), characterized in that a ratio of c/d

of collapse pressure after expansion and collapse pressure before expansion is in the range of 1 to 1.2, where

c: collapse strength (MPa) after expansion 10 to 20% and aging at 80 to 200°C, and d: collapse strength (MPa) of unexpanded steel pipe of same dimension as steel pipe measured for c.

(5) A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to any one of (1) to (4), characterized in that a welded part is normalized or quenched and tempered.

(6) A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to any one of (1) to (5), characterized in that the seam portions are butt welded.

(7) A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to any one of (1) to (6), characterized in that expanding the pipe by extracting a plug of a diameter larger than the inside diameter of the steel pipe.

(8) A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to any one of (1) to (7), characterized by being used expanded on an oil well drilled into the ground.

(9) A method of production of oil country tubular goods excellent in collapse characteristics after expansion according to any one of (1) to (8), characterized by circulating fluid of 80 to 200°C through the oil well after expansion.

[0007]

[Best mode for carrying out the invention]

The inventors engaged in detailed studies on the effects on the Bauschinger effect and its recovery behavior by the methods of production, structures, and chemical compositions of steels and the solid solution state of the added elements and in particular took note of the coiling temperature after hot rolling and cooling. They heated steel slabs of various

chemical compositions to the austenite region, subjected them to rough rolling and finishing rolling, then cooled the strips and coiled them in the temperature range of 300 to 700°C. After this, they made pipes and studied in detail the effects of the coiling temperature on the collapse pressure due to the Bauschinger effect after expansion and evaluated the same by the ratio between the collapse pressure of the steel pipe after expansion and the collapse pressure of the steel pipe before expansion. Note that the collapse pressure is affected by the dimensions of the steel pipe, so the collapse pressure of the steel pipe before expansion was measured as the collapse pressure of steel pipe of the same dimensions as after expansion but unexpanded.

[0008]

As a result, it was learned that steel produced by hot rolling, then coiling in the temperature range of 500 to 700°C ended up dropping about 30% from the collapse pressure before expansion due to the Bauschinger effect after expansion. Further, the collapse pressure dropping due to expansion did not improve by low temperature ageing at about 100°C, but recovered to the same level as the collapse pressure before expansion if heat treatment was performed at a temperature of 300°C or more.

[0009]

As opposed to this, they learned that the drop in collapse pressure of steel having a coiling temperature of 300°C or less was at most 15% from the collapse pressure before expansion. Further, the compression yield strength which dropped due to the Bauschinger effect rose due to low temperature ageing at about 100°C, reached the collapse value before expansion or more, and became a collapse pressure 20% higher than the unexpanded pipe in some cases. This extent of low temperature ageing can be performed utilizing the natural temperature in an oil well and is easily realized artificially as well.

Therefore, recovery of the compression yield strength by low temperature ageing of about 100°C is particularly important for raising the collapse pressure of steel pipe expanded in an oil well.

The inventors investigated the microstructure of steels coiled at 300°C or less and as a result learned that they have structures including low temperature transformation phases such as upper bainite. Such low temperature transformation phases are believed to suppress the drop in compression yield strength due to the Bauschinger effect. Further, the reasons why the compression yield strength after expansion rose to equal or more than the compression yield strength before expansion by the low temperature ageing at about 100°C are considered to be the easy change of stress locations around dislocation causing the Bauschinger effect and the fixing at dislocation of C and other elements present in the solid solution state. Therefore, it is extremely important not to perform any heat treatment after coiling hot rolled steel strip, but to form pipe as is to produce steel pipe.

[0010]

In this way, steel pipe may be produced in principle by seamless rolling as well, but with seamless steel pipe, large working at a temperature corresponding to the finishing rolling is not possible. Therefore, as-rolled seamless steel pipe has the defects of a large crystal grain size and a low yield strength of the material, so a low collapse pressure and further large unevenness of thickness, so susceptibility to bending during expansion.

[0011]

Next, the reasons for limitation of the chemical ingredients included in the oil country tubular goods according to the present invention will be explained. Basically, the chemical ingredients are limited to ranges giving high strength steel strip of a thickness of 7 mm to 20 mm with a strength of 550 MPa to 900 MPa required for oil country tubular goods under

the above production conditions and having excellent toughness, in particular a small drop in low temperature toughness due to expansion and ageing.

[0012]

C is an element essential for enhancing the hardenability and improving the strength of the steel. The lower limit required to obtain the target strength is 0.03%. However, if the amount of C is too great, with the process of the present invention, the strength becomes too high and a remarkable deterioration in the low temperature toughness is invited, so the upper limit was made 0.30%.

[0013]

Si is an element added for deoxygenation or improvement of strength, but if added in an amount greater than this, the low temperature toughness is remarkably deteriorated, so the upper limit was made 0.8%. Deoxygenation of steel is also sufficiently possible by Al and Ti as well. Si does not necessarily have to be added. Therefore, no lower limit is defined, but usually this is included in an amount of 0.1% or more as an impurity.

[0014]

Mn is an element essential for enhancing the hardenability and securing a high strength. The lower limit is 0.3%. However, if the amount of Mn is too great, martensite is produced in a large amount and the strength becomes too high, so the upper limit was made 2.5%.

[0015]

Further, the steel of the present invention contains as essential elements Nb and Ti.

[0016]

Nb not only suppresses recrystallization of austenite to make the structure finer at the time of rolling, but also contributes to an increase of the hardenability and toughens the steel. Further, it contributes to the recovery from the Bauschinger effect by the ageing. The effect is small if the

amount of Nb added is less than 0.01%, so this is made the lower limit. However, if greater than 0.3%, the low temperature toughness is adversely affected, so the upper limit was made 0.3%.

[0017]

Ti forms fine TiN and suppresses the coarsening of the austenite grains at the time of slab reheating to make the microstructure finer and improve the low temperature toughness. Further, if the amount of Ai is a low one of for example not more than 0.005%, Ti forms oxides and therefore has a deoxygenation effect as well. To manifest this effect of TiN, a minimum of 0.005% of Ti has to be added. However, if the amount of Ti is too great, coarsening of TiN or precipitation hardening due to TiC occur and the low temperature toughness is degraded, so the upper limit was limited to 0.03%.

[0018]

Al is an element usually included in steel as a deoxygenating material and has the effect of making the structure finer as well. However, if the amount of Al is over 0.1%, the Al-based nonmetallic inclusions increase and detract from the cleanliness of the steel, so the upper limit was made 0.1%. However, deoxygenation is also possible with Ti and Si, so Al does not necessarily have to be added. Therefore, no lower limit is limited, but usually 0.001% or more is included as an impurity.

[0019]

N forms TiN, suppresses the coarsening of the austenite grains at the time of slab reheating, and improves the low temperature toughness of the base material. The minimum amount required for this is 0.001%. However, if the amount of N becomes too great, the TiN is coarsened and surface defects, deteriorated toughness, and other problems occur, so the upper limit has to be suppressed to 0.01%.

[0020]

Further, in the present invention, the amounts of the

impurity elements P and S are made 0.03% and 0.01% or less. The main reason is to further improve the low temperature toughness of the base material and improve the toughness of the weld. Reduction of the amount of P mitigates the center segregation of the continuously cast slab and prevents grain destruction to improve the low temperature toughness. Further, reduction of the amount of S reduces the MnS drawn by hot rolling and improves the drawing toughness in effect. With both P and S, the less the better, but this has to be determined by the balance of characteristics and cost. Normally P and S are contained in amounts of 0.01% or more and 0.003% or more.

[0021]

Next, the objects of adding the optional elements Ni, Mo, Cr, Cu, V, Ca, and REM will be explained. The main object of adding these elements is to try to further improve the strength and toughness and increase the size of the steel material which can be produced without detracting from the excellent features of the steel of the present invention.

[0022]

The object of adding Ni is to suppress deterioration of the low temperature toughness. Addition of Ni, compared with addition of Mn or Cr and Mo, seldom forms a hard structure harmful to low temperature toughness in a rolled structure, in particular the center segregation zone of a continuously cast slab. However, if the amount of Ni is less than 0.1%, this effect is not sufficient, so addition of 0.1% or more is desirable. On the other hand, if the amount added is too great, martensite is produced in large amounts and the strength becomes too high, so the upper limit was made 1.0%.

[0023]

Mo is added to improve the hardenability of steel and obtain a high strength. Further, it also acts to promote recovery from the Bauschinger effect by the low temperature ageing at 100°C or so. Further, Mo is also effective in suppressing recrystallization of austenite at the time of

controlled rolling together with Nb and in making the austenite structure finer. To express this effect, Mo is preferably added in an amount of 0.05% or more. On the other hand, excessive addition of Mo results in martensite being produced in large amounts and the strength becoming to high, so the upper limit was made 0.6%.

[0024]

Cr increases the strength of the base material and welded part. To achieve this effect, Cr is preferably added in an amount of 0.1% or more. On the other hand, if the amount of Cr is too great, martensite is produced in large amounts and the strength becomes to high, so the upper limit was made 1.0%.

[0025]

V has substantially the same effect as Nb, but the effect is weak relative to Nb. To make it sufficiently manifest this effect, it is preferable that it be added in an amount of at least 0.01%. On the other hand, if the amount added is too great, the low temperature toughness is degraded, so the upper limit was made 0.3%.

[0026]

Ca and REM control the form of the sulfides (MnS etc.) and improve the low temperature toughness. To obtain these effects, it is preferable to add Ca in an amount of 0.001% or more and REM in an amount of 0.002% or more. On the other hand, if the adding Ca in an amount more than 0.01% and REM more than 0.02%, a large amount of CaO-CaS or REM-CaS is produced resulting in large sized clusters and large sized inclusions and impairs the cleanliness of the steel. Therefore, the upper limit of the amount of addition of Ca was limited to 0.01% and the upper limit of the amount of addition of REM was limited to 0.02%. Note that a preferable upper limit of the amount of addition of Ca is 0.006%.

[0027]

Next, the production conditions for oil country tubular goods containing the above ingredients will be explained.

[0028]

The present invention limits the coiling temperature after hot rolling and cooling to not more than 300°C. This is the most fundamental point of the aspects of the invention and is an essential condition for forming an upper bainite or other low temperature transformation structure and causing residual elements in solid solution. Due to this, steel pipe is obtained which is excellent in strength and toughness, features little drop in collapse pressure after expansion, and further is improved in collapse pressure due to ageing. If the coiling temperature becomes higher than 300°C, the structure becomes mainly ferrite, precipitation occurs, and the desired effect can no longer be obtained. That is, the drop in collapse pressure due to the Bauschinger effect after expansion becomes great and the dropped collapse pressure can no longer be improved by low temperature ageing. On the other hand, the lower limit of the coiling temperature is not particularly limited in terms of characteristics, but sometimes is limited by the coiling capacity of the production facility. At the current level of technology, a range of 50 to 150°C is the lower limit possible with normal production.

[0029]

Steel pipe obtained by shaping hot rolled steel strip produced by coiling at not more than 300°C into a tube as is and then welding the seam in this way has a small drop in the collapse pressure after expansion. The ratio a/b of the collapse pressure <u>a</u> of the steel pipe after expansion 10 to 20% and the collapse pressure <u>b</u> of steel pipe of the same composition and dimensions as <u>a</u> but unexpanded is 0.85 to less than 1.

[0030]

Further, if ageing after expansion, the collapse pressure recovers to an equal or higher level than before expansion. The ratio c/d of the collapse pressure <u>c</u> of the steel pipe aged at

80 to 200°C after expansion 10 to 20% and the collapse pressure d of the steel pipe of the same composition and dimensions as c but not expanded becomes a range of 1 to 1.2. The ageing temperature range was made 80 to 200°C because this is the temperature range enabling natural ageing in an oil well. The ageing is sufficiently effective at a temperature of about 100°C. The low temperature toughness after ageing falls somewhat along with a rise in temperature. Therefore, the temperature range of the ageing is preferably 80 to less than 150°C. Further, the holding time has to be about 30 minutes to raise the collapse pressure. The effect of raising the collapse pressure by low temperature ageing becomes saturated by holding for 24 hours, but when using the natural temperature in a well, a time of longer than 24 hours does not pose any particular problem. Long time treatment is not excluded.

[0031]

Note that in general the welded part and heat affected zone become lower in low temperature toughness, so when necessary it is possible to heat the welded part to the austenite region and allow it to cool (normalization) or quench and temper it. The heating temperature of the normalization and quenching is preferably 900 to 1000°C. If under 900°C, the austenitization is sometimes insufficient, while if over 1000°C, the crystal grains become coarser. The tempering is preferably performed at 500 to 700°C. If under 500°C, the tempering effect is not sufficient, while if over 700°C, transformation to austenite occurs. Normally, this treatment is performed by an induction heating apparatus after making the pipe, so the holding time is about several tens of seconds.

[0032]

The method of shaping the steel pipe may be a generally used method of shaping steel pipe such as press forming or roll forming. Further, the method of welding the seam used may be laser welding, arc welding, or electric resistance welding, but

an electric resistance welding process is high in productivity and gives a small welding heat affected zone, so is suited to production of the oil country tubular goods of the present invention.

[0033]

The thus produced oil country tubular goods is expanded to the targeted expansion rate of 10 to 20% or so. Note that the "expansion rate" is the rate of change of the outside diameter of the steel pipe from before to after expansion. This expansion may be performed by inserting a plug having a diameter larger than the inside diameter of the steel pipe and corresponding to the inside diameter after expansion and extracting the plug through the inserted oil country tubular goods from the bottom to the top by the drive power of water pressure from below the plug or a wire pulling it upward.

[0034]

Such expansion can be performed by inserting the pipe into a well in the ground drilled by a drill pipe or a well in which another oil well pipe has already been placed. Wells sometime reach depths of several thousands of meters. In general, the deeper in the ground, the higher the temperature. Temperatures are frequently over 100°C. In such a case, the steel pipe of the present invention is aged at a low temperature after expansion and improved in collapse pressure compared with before expansion.

[0035]

Further, at shallow parts of the ground, the temperature is sometimes lower than 80°C. At such a time, it is possible to greatly improve the collapse pressure by low temperature ageing artificially raising the temperature to 80 to 200°C and holding the temperature there for 30 minutes to 24 hours. Note that the low temperature ageing is effective at about 100°C. The low temperature toughness falls somewhat along with a rise in temperature. Further, if considering economy, the range of the

ageing temperature is preferably 80 to less than 150°C. Further, the holding time has to be about 30 minutes to improve the collapse pressure. Further, at 24 hours, the effect becomes saturated, but there is no particular problem even if holding for more than this time. This low temperature ageing for example suppresses collapse when drilling a well. Since a fluid (mud) is filled in the well for the purpose of recovering scraps, it is possible to heat this mud to 80 to 200°C and circulate it for the ageing.

[0036]

[EXAMPLES]

(Example 1)

Steels having the chemical compositions shown in Table 1 were produced by a converter and continuously cast to steel slabs which were then hot rolled by a continuous hot rolling machine to hot rolled steel strips of 12.7 mm thickness. The hot rolling was ended at 950°C, then the strips were cooled by the cooling rates shown in Table 2 and coiled. The hot rolled steel strips were used to produce steel pipes of outside diameters of 193.7 mm by the electric resistance welding process. Some of the pipes were quenched and tempered or normalized at the welded parts by a high frequency power source arranged on the production line. The quenching and tempering were performed by heating at 960°C for 60 seconds, then water cooling from the outside surface, then heating at 680°C for 60 seconds and allowing the result to cool. Further, the normalization was performed by heating at 960°C for 60 seconds, then allowing the result to cool.

[0037]

After this, the pipes were expanded to give a change of the outer circumference of 20% by plug insertion to obtain steel pipes of outside diameters of 232.4 mm. Some were aged for 2 hours by the temperatures shown in Table 2. Further, as the comparative materials for evaluating the change of the

collapse pressure due to expansion, steel pipes having outside diameters of 232.4 mm were produced from the same hot rolled steel strips but not expanded. Some were aged at 2 hours at the temperature shown in Table 2.

[0038]

The thus produced steel pipes were used for collapse tests and Charpy tests. The collapse tests were performed using pipes of lengths 10 times the pipe diameters as test samples under open end conditions where no stress occurred in the pipe axial direction. For the pressure medium, water was used and pressurized. The water pressure when the pressure dropped was used as the collapse pressure. The Charpy tests were conducted in accordance with JIS Z 2202 using V-notched test samples in a temperature range of -60°C to room temperature.

[0039]

The results are shown in Table 2. The effects of expansion and ageing on the collapse pressure were expressed by the ratios a/b and c/d with the collapse pressures of comparative materials produced without expansion. The Charpy absorbed energy aimed at was the 80J or higher at -20°C believed to be sufficient for oil country tubular goods. Nos. 1 to 12 were in the range of examples of the present invention and had ratios a/b of the collapse pressure of 0.9 or higher. In particular, with ageing, c/d rose to 1.0 or more.

[0040]

On the other hand, No. 13 had a coiling temperature higher than the range of the present invention and a low c/d. No. 14 had a c/d of more than 1.0, but the ageing temperature in this case was 350°C. This temperature is outside the present invention and cannot be realized in an oil well. Further, No. 15 had an amount of Nb smaller than the range of the present invention, so the c/d was low. Nos. 16 and 17 had Mn and C more than the ranges of the present invention, so their c/d's were low and their Charpy absorption energies fell.

[0041]

[Table 1]

Steel no.	Chemical composition (wt%)																Remarks
	C	Si	Mn	P	S	Nb	Ti	Al	N	Ni	Mo	Cr	V	B	Ca	REM	
A	0.08	0.24	1.86	0.016	0.002	0.052	0.015	0.032	0.0035	-	-	-	-	-	-	-	Inv. ex.
B	0.06	0.36	0.76	0.012	0.003	0.034	0.012	0.045	0.0028	-	0.25	-	0.03	-	0.002	-	
C	0.04	0.15	0.53	0.008	0.008	0.061	0.021	0.056	0.0042	-	0.12	-	-	0.0012	-	-	
D	0.22	0.41	0.95	0.023	0.001	0.039	0.013	0.018	0.0026	0.25	-	-	-	-	-	0.004	
E	0.15	0.25	1.28	0.015	0.004	0.044	0.017	0.052	0.0039	-	-	0.45	-	-	-	-	
F	0.12	0.26	1.34	0.013	0.002	<u>0.003</u>	0.016	0.061	0.0037	-	-	-	-	-	-	-	Comp. ex.
G	0.07	0.17	<u>3.1</u>	0.014	0.002	0.049	0.014	0.033	0.0029	-	0.13	-	-	-	-	-	
H	<u>0.32</u>	0.31	1.61	0.008	0.002	0.045	0.014	0.033	0.0036	-	-	-	-	-	-	-	

- in table indicate below limit of detection. Underlines indicate outside scope of present invention.

[0042]

[Table 2]

Ex. no.	Steel no.	Coiling temperature (°C)	Structure*	Yield strength (MPa)	Welded part heat treatment	Ageing temperature (°C)	Collapse pressure MPa		Charpy absorbed energy J	Comparative material collapse pressure MPa		a/b	c/d	Remarks
							a	c		b	d			
1	A	200	BF+B	621	None	None	47	-	156	50	-	0.94	-	Inv. ex.
2			BF+B		Quenching and tempering	100	-	53	152	-	50	-	1.06	
3			BF+B		None	180	-	59	141			-	1.18	
4		130	BF+B	646	None	None	48	-	148	52	-	0.92	-	
5	B	260	BF+B	633	Normalization	None	47	-	171	51	-	0.92	-	
6			BF+B			100	-	52	171	-	51	-	1.02	
7	C	230	BF+B	578	None	None	45	-	189	48	-	0.94	-	
8			BF+B			100	-	49	179	-	48	-	1.02	
9	D	220	BF+B	661	Quenching and tempering	None	52	-	98	56	-	0.93	-	
10			BF+B			100	-	56	89	-	56	-	1.00	
11	E	190	BF+B	702	Normalization	None	53	-	97	58	-	0.91	-	
12			BF+B			100	-	59	84	-	58	-	1.02	
13	A	510	F+P	583	None	100	-	34	145	48	48	-	0.71	Comp. ex.
14			F+P			350	-	51	145			-	1.06	
15	F	852	BF+B	643	None	None	-	33	121	52	52	-	0.63	
16	G	857	BF+B	913	None	100	-	50	56	61	61	-	0.82	
17	H	810	BF+B	955	None	100	-	42	32	65	65	-	0.65	

Underlines are conditions outside scope of present invention.

Ageing time = 2 hours

*BF: bainitic ferrite, B: bainite, M: martensite

[0043]

[Effect of the invention]

According to the present invention, it is possible to provide oil country tubular goods excellent in collapse characteristics after expansion in an oil well pipe. In particular, since the collapse pressure is restored by low temperature ageing at 100°C or so possible in an oil well, this is optimal as oil country tubular goods used in a well.

[Name of document] Abstract
[Abstract]
[Problem] The present invention provides a method of production of oil country tubular goods having a small drop in collapse pressure after expansion and having a collapse pressure recovering by low temperature ageing at about 100°C and oil country tubular goods obtained by this method of production.
[Solving the problem] This method of production comprises hot rolling a steel slab having amounts of addition of C, Mn, P, S, Nb, Ti, Al, and N in specific ranges and having a balance of iron and unavoidable impurities and shaping the steel strip coiled at a temperature of not more than 300°C as it is into a tube. The steel pipe further contains one or more of Ni, Mo, Cr, Cu, V, B, Ca, REM in the specified amount.
[Selected drawings] None